THE HYDRAULIC FRACTURING PROCESS (HF): REAL CONCERN or MISDIRECTED FOCUS CONCERNING THREATS TO DRINKING WATER SUPPLIES (DWS)

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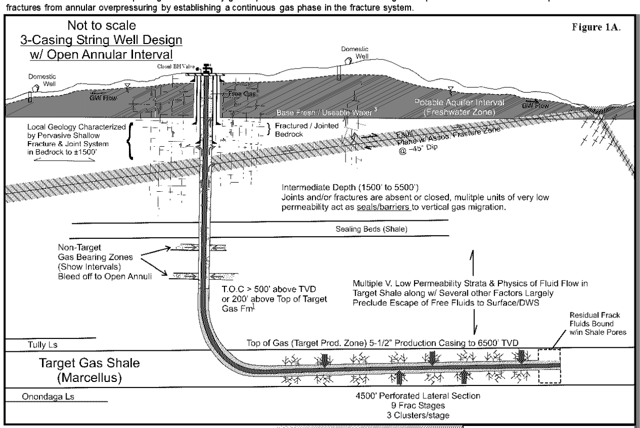
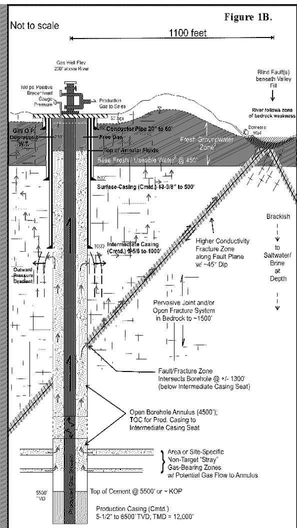
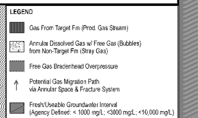
Introduction

This author's literature review, attendance at various hydraulic fracturing (HF) symposiums, forums, conferences, an EPA sponsored HF workshop on Fate & Transport and discussions with oil and gas regulatory agencies and industry representatives suggest there is a growing, if not already strong consensus among those who have performed objective analyses of the HF process, that the risk posed to potable aquifers or drinking water supplies (DWS) from the deep underground process of HF is now miniscule. Assessments of potential impacts range from "remote" (DOE 90 Day Report) to "do not present a reasonably foreseeable risk of significant adverse environmental impacts" (NYS SGEIS). Furthermore, multiple lines of evidence including theory based on the physics of fluid flow, fate and transport modeling and empirical evidence from hundreds of thousands of frac jobs performed by industry in the last 60+ years without documented impacts to DWS, indicate that further public focus on this concern is misdirected and simply unwarranted. It is often a challenge for experts to communicate complex concepts to the public to allay fears and concerns. Terms such as imbibition, irreducible water saturation, and capillary pressure effects and their underlying conceptual basis while critical to a technical understanding of why 70% to 90% of frac fluids remain unrecovered in flow back, also make it difficult to convey to the public why these residual frac fluids are highly unlikely to subsequently appear in a DWS. Residual frac chemicals are most likely locked in rock pores of the target shale with no means of escape for periods possibly on a scale approaching that of geologic time. The public rarely differentiates between direct impacts by methane gas to DWS, and their contamination with other constituents from other mechanisms or processes. Direct impacts by methane gas to DWS have occurred, and documented pathways for this type of contamination do exist related to gas well construction, when an uncemented annulus becomes over pressured. However, in most instances methane occurrence in DWS is still attributable to sources unrelated to gas development. When methane impacts from gas development do occur, they are most typically related to non-routine overpressuring "events" during drilling, cementing or casing operations unrelated to the hydraulic fracturing process itself. Some well design practices can facilitate stray gas migration when site-specific geologic conditions, as depicted here, are not fully understood. Specifically, should shallow fractured bedrock extend below surface (two-string design) or intermediate (3-string design) casing depths, higher risks for gas migration may be present.

This poster illustrates two pathways for stray gas migration that may occur independently of each other, or operate in conjunction, to facilitate gas migration to a DWS when a 3-string casing design with open annulus becomes overpressured. From a relative threat standpoint, a change in focus from potential hydraulic fracking fluid impacts to DWS, to the real threat of stray gas migration, is long overdue. While public concerns about HF fluid impacts to DWS have brought about better regulation and many operational improvements by industry, including frac chemistry disclosures (e.g. fracfocus.org), use of less/non-toxic (green) chemical substitutes and greater transparency of overall operations, few significant additional environmental gains in this area are likely to occur that further reduce risk in any appreciable manner from its already low state. Further, opponent arguments and concerns regarding impact to DWS from the hydraulic fracturing process appear increasingly without technical merit. In contrast to frac fluids largely sequestered in the target formation, methane gas from non-target gas bearing zones is abundant and concentrated, can be highly mobile and migrate as a free phase in addition to dissolved phase, has a pathway that permits several thousand feet of cross-strata migration (open annulus above production casing cement) and a drive mechanism (buoyancy). Furthermore, methane from a deeper source (normal to over pressured gas bearing geologic unit) often leads to over pressuring of casing and annular intervals at shallow depths (i.e. exceed hydrostatic conditions). Overpressuring is undesirable and mitigation/remediation can be problematic and costly or result in continuous venting of this potent GHG over a long period (e.g. life of well). Gas build up (overpressuring) of the annulus can also create the required gradient for stray gas to penetrate fractured bedrock through the open borehole wall and move upward and around surface/intermediate casing strings of good integrity to reach a DWS. Earlier overpressure events (e.g. gas kicks) during the drilling and completion phase may also facilitate subsequent movement through shallow fractures from annular overpressuring by establishing a continuous gas phase in the fracture system.

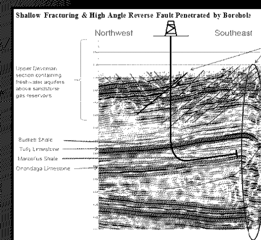




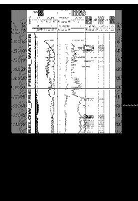


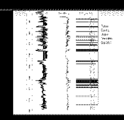
NOTES:

1. 200' for TOC in Figure 1A applies to minimum height above top of perforations in vertical or slant wells only (PA DEP).
2. Positive bradenhead gauge pressure not to exceed 80% x hydrostatic pressure at depth of surface casing shoe per PA DEP (.80 x 0.433 psi/ft. x 500' = 173 psi in this example Figure 1B).
3. Base of fresh/useable water (1000 mg/L, NYDEC; 3000mg/L, some other states; 10,000 mg/L some otherstates, EPA and BLM (Onshore Order #2).
4. Neither figure depicts slower gas migration through cement that can sometimes occur. These are referred to as mechanical discontinuities that create annular conductivity. They include micro-annular flow (between cement sheath and casing or borehole wall) or matrix permeability/channeling when a slug of gas enters the cement and migrates upward before the cement sets. This is most common in the GOM where shallow overpressured gas zones that lie opposite cemented casing strings can lead to sustained (annular) casing pressures (SCM). That stray gas may also require venting.



Zone of deep-seated vertical faults and fracture swarms related to transpressive faulting. These large scale fault systems occur throughout the Appalachian region and can serve as naturally-occurring vertical conduits for gas migration from deep seated gas source rocks (Ordovician and Devonian shales) up to the near-surface gas sands in the Upper Devonian Lock Haven and Catskills Formations. Fresh groundwater aquifers also are formed in heavily fractured areas of these same Upper Devonian rocks and in near-surface glacial alluvium.

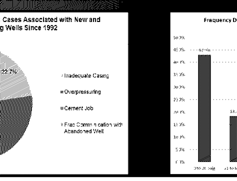


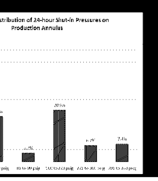


Key Questions:

1. How accurate are these subsurface representations of stray gas migration, relative to frac fluids, and what are the reasonable pathways (shown or not shown)?
2. When an annulus becomes overpressured, can significant amounts of methane gas (enough to impact DWS) penetrate the borehole wall in the dissolved phase or only in the free gas phase (i.e. this requires sufficient overpressuring to drive the water level in the annulus below the intermediate casing seat or further downward than in the case above, so that free gas is opposite the borehole wall)?
3. If venting is the preferred management solution to prevent borehole annuli from overpressuring, what quantity of methane is being released to the atmosphere by this standard practice?
4. Given that frac fluids have not been documented to impact DWS (few pathways exist), while methane related to stray gas migration has been implicated in several cases (due to a documented drive mechanism and a pathway), where are limited resources better spent?

Evidence that stray gas, its monitoring and its proper management is a concern in PA DEP





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Conclusions

Relative to HF fluids used in fracing target gas shales, stray gas from non-targeted (noncommercial) gas bearing zones found above targeted gas is far more abundant, concentrated and mobile with much greater upward migration potential from the deep subsurface due to the buoyancy drive mechanism within an open borehole annulus. A several thousand foot potential cross-strata migration pathway exists to DWS via the open borehole (open annular space between top of production casing cement and cemented surface or intermediate casing string/shoe) under most current well designs accepted by states and the BLM. Should an overpressured annulus develop from these gas sources and an open fractured/jointed condition characterize shallow bedrock that extends below surface or intermediate casing depths, this gas migration pathway to DWS is potentially complete. With the advent of unconventional shale resource plays, their expansive coverage, increased well densities and intermingling with rural domestic wells, greater risk over the long term exists from non-routine annular overpressuring events or when wells are not vented. Mitigation of annular space methane gas build up through venting is less of an option than in the past due to concerns for GHG emissions as this methane source is poorly quantified. The complexity of the stray gas migration issue suggests further research into its component parts is warranted for a better understanding of best management practices. These include **1) Quantification** of the nature of the problem or approximate amount of stray gas currently vented by the gas industry, possibly through a random/probabilistic sampling design **2) Source Identification & Isolation** – methods of source (strata) identification (borehole logging options), zonal isolation, conditions fostering or limiting flow/bleed-off to well bore/annulus **3) Annular Environment** – effects of fluids present (water, mud, brine, gas), gas transport phase (free phase gas vs. dissolved), slough/cave (borehole bridging effects) and their effect on gas flow from the source to the borehole and outward to country rock from overpressuring **4) Overpressure Conditions** – gas phase and entry pressure requirements for rock matrix vs. fracture (pore & aperture minimums), wetting phase of matrix/fracture faces, residual effects from non-routine overpressure "events" that would facilitate gas connectedness in fractures and subsequent stray gas migration **5) Monitoring** – casing annular pressures correlation with annular fluid levels, freshwater zone heterogeneity (stratification) and appropriate freshwater intervals or aquifer horizons for early detection of methane migration to DWS. There are many trade-offs in selecting management strategies and well designs to minimize stray gas. Further analysis of the components is warranted to better assess cost-benefit relationships and to ensure that GHG emissions and potential impacts to DWS are minimized.

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Disclaimer: This poster is of an interpretive nature and reflects the author's assimilation of the published work of many researchers and information from discussions with regulatory agency staff. Its purpose is to foster informed discussion of the potential impacts from stray gas migration to drinking water supplies in the context of unconventional resource plays.

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